# The Deep Space Network


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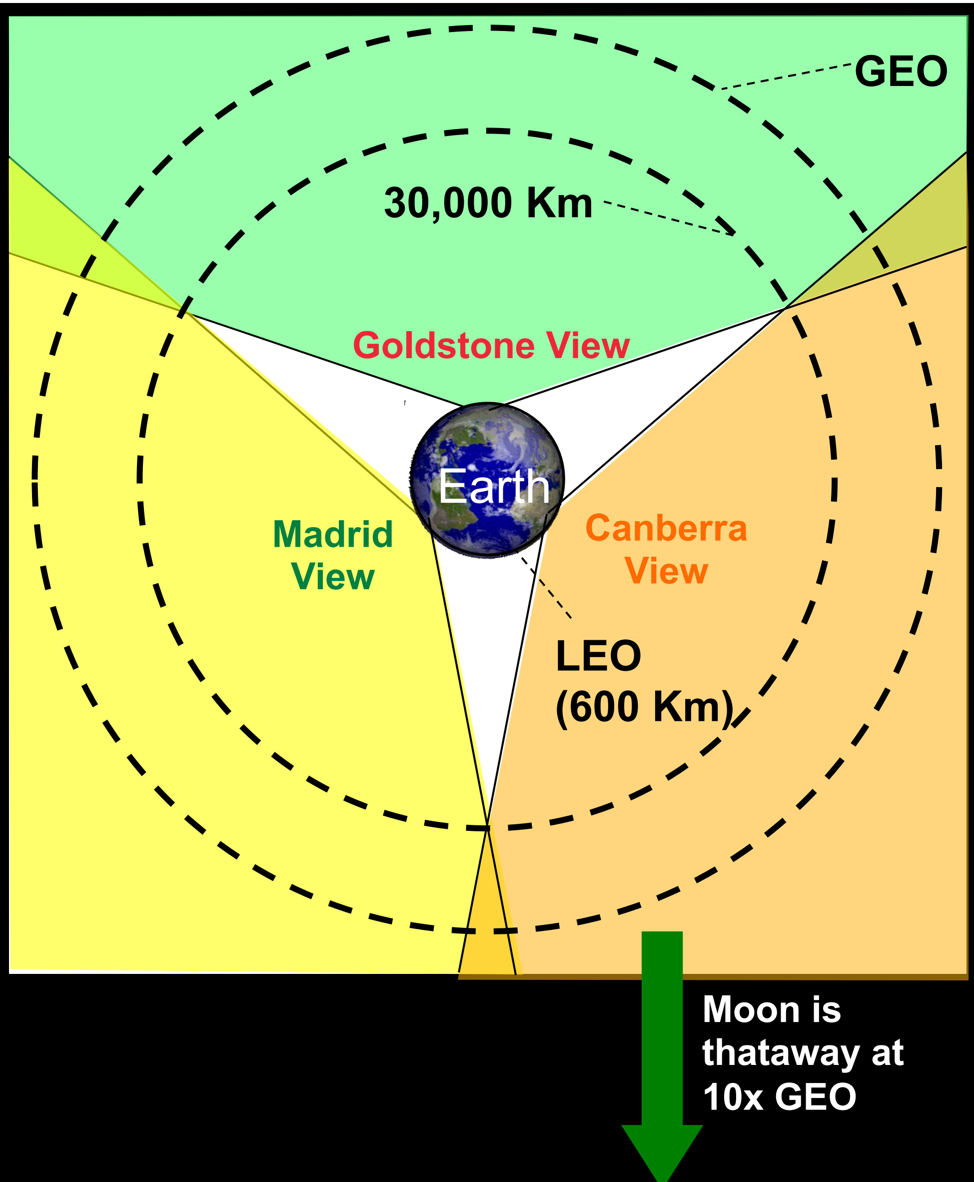
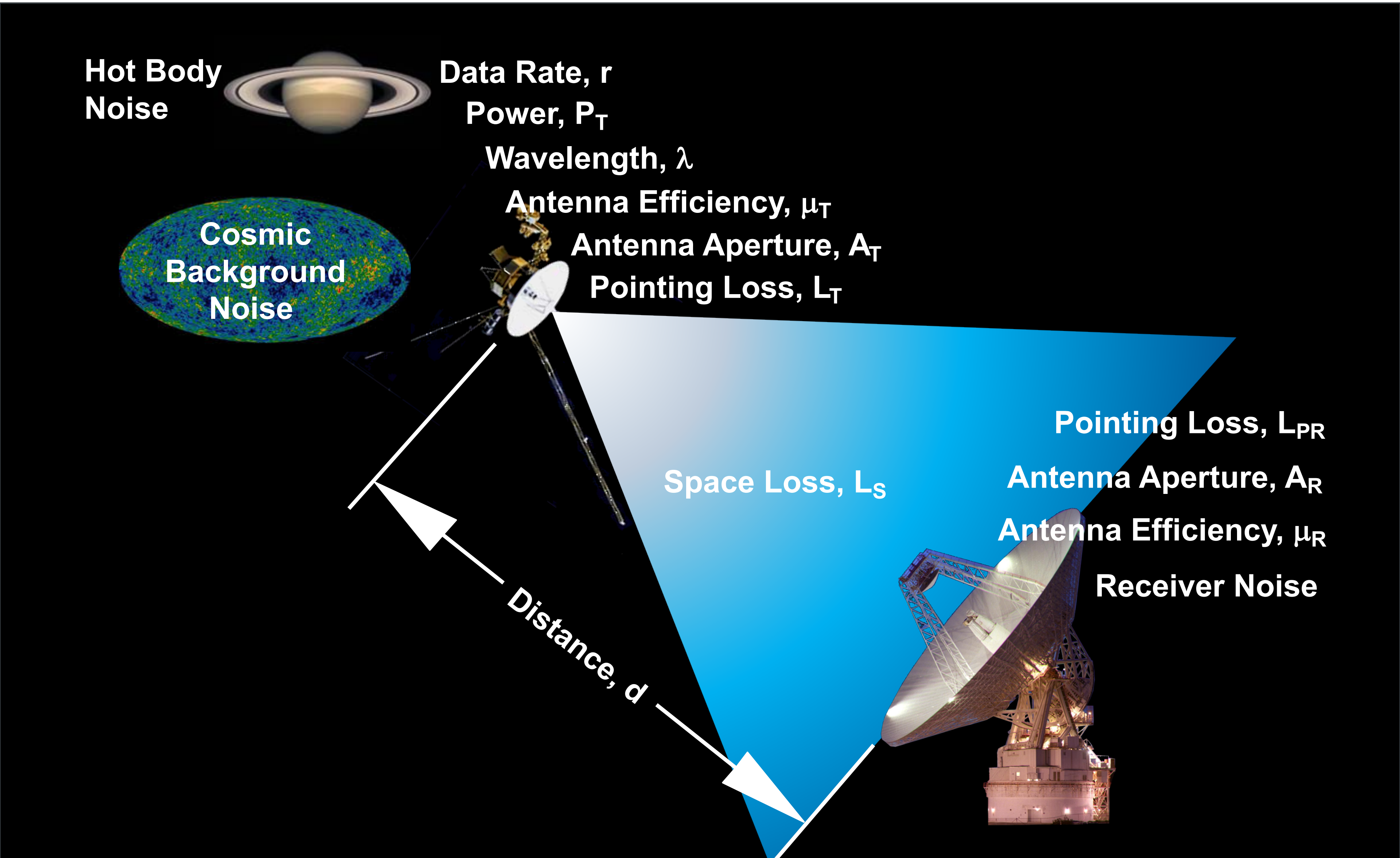
# DSN Antennas in Canberra, Australia

# A Global Enterprise by Necessity

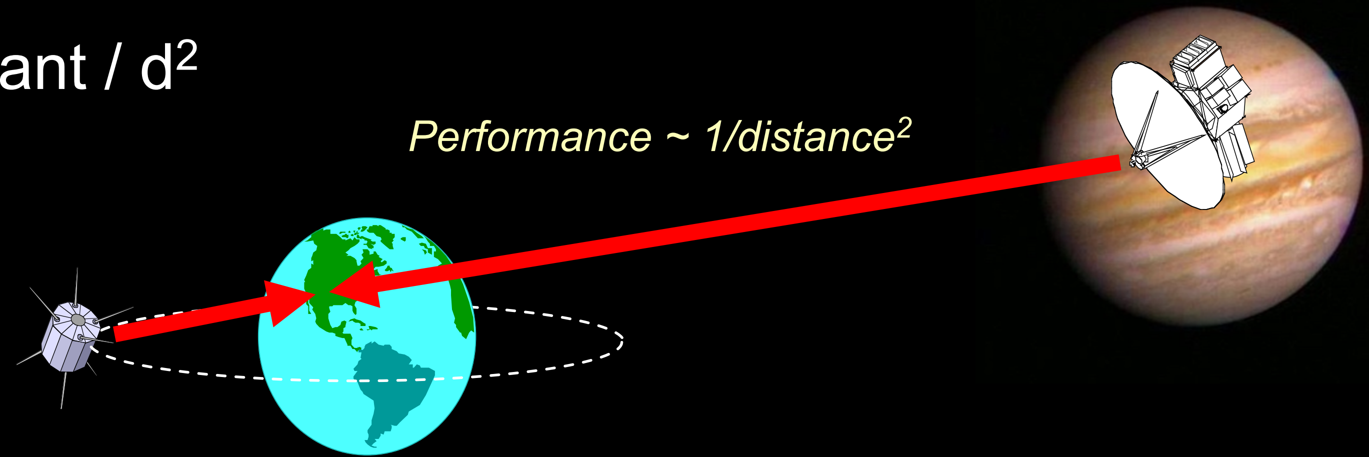


# Deep Space Communications



# Why Deep Space Communications is Hard

$E_b/N_0$ = constant / $d^2$

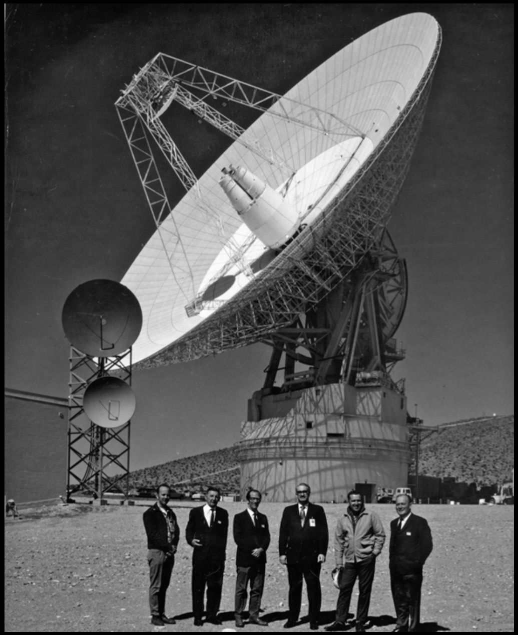



*Relative Difficulty*

| *Place* | *Distance* | *Difficulty* |
|---|---|---|
| *GEO* | *$4x10^4$ km* | *Baseline* |
| *Moon* | *$4x10^5$ km* | *100* |
| *Mars* | *$3x10^8$ km* | *$5.6x10^7$* |
| *Jupiter* | *$8x10^8$ km* | *$4.0x10^8$* |
| *Pluto* | *$5x10^9$ km* | *$1.6x10^{10}$* |

# History of Ground Antennas

1958, 26m Station



1966, 64m Station

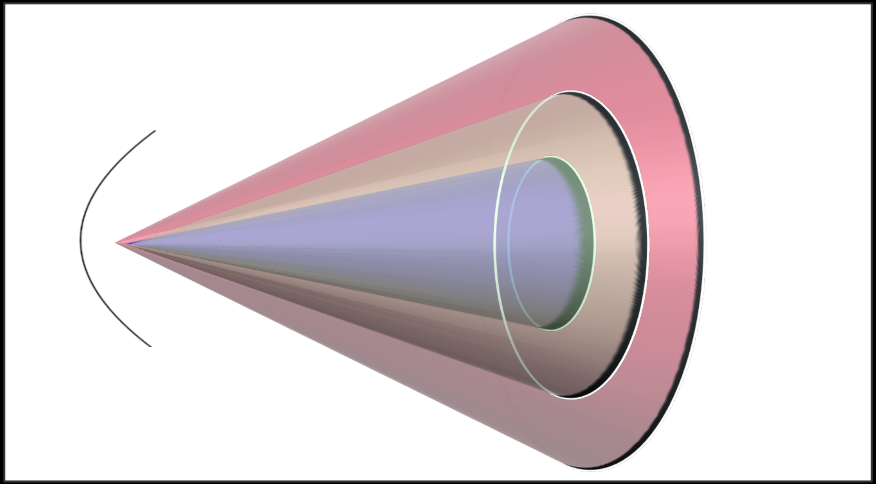
1979, 34m Station

1988, 70m Station
(converted from prior 64 antennas)

# Higher Frequency is Good

$$E_b/N_0 = \text{constant} * f^{\,2}$$

- Fist deep space missions transmitted at 960 MHz
- 2.2 GHz (S-band) became standard in 1969
- 8.4 GHz (X-band) became prevalent in the early 1970s
- 32 GHz (Ka-band) is now becoming the standard



# Lowering the System Noise

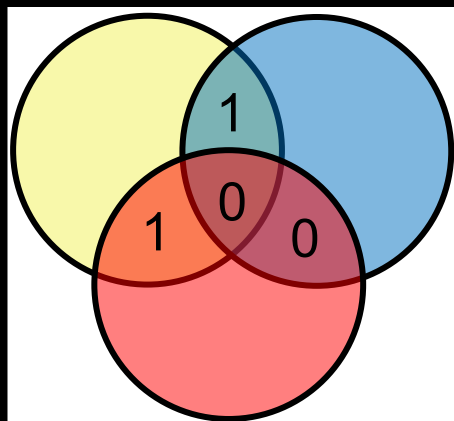
$E_b/N_0$ = constant/T

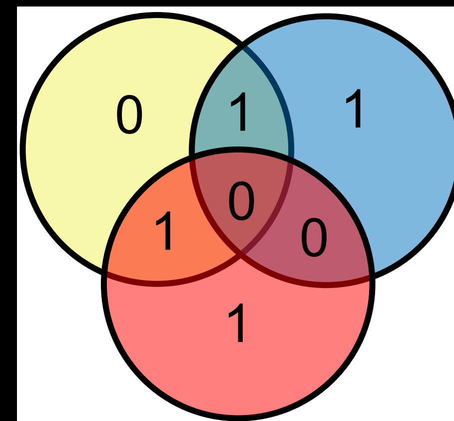
- Some of T cannot be controlled
- Focus on contributions from spacecraft and DSN
- Avoid interference
  - Our own spectrum from the ITU
- Best low noise amplifiers we can
  - Physical temperature is ~12 K


**Ka-band (32 GHz) low noise amplifier**

# Eror Korecting Cods

An example of coding: the (7, 4) Hamming code

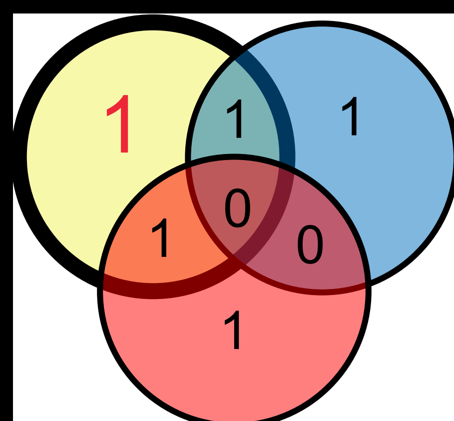


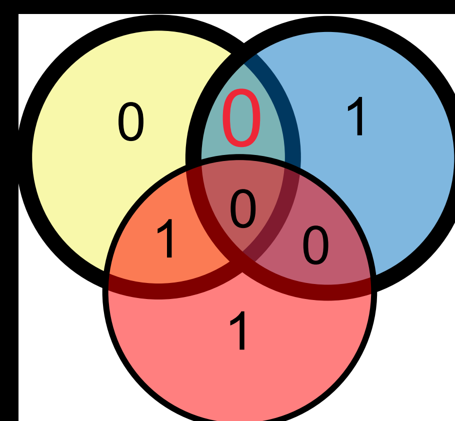




Place 4 information bits in the intersections of the Venn diagram

Fill in the diagram so that the circles have an even number of 1's

If a single error occurs, it can be corrected by locating the circles with an odd number of 1's and changing the bit in their intersection

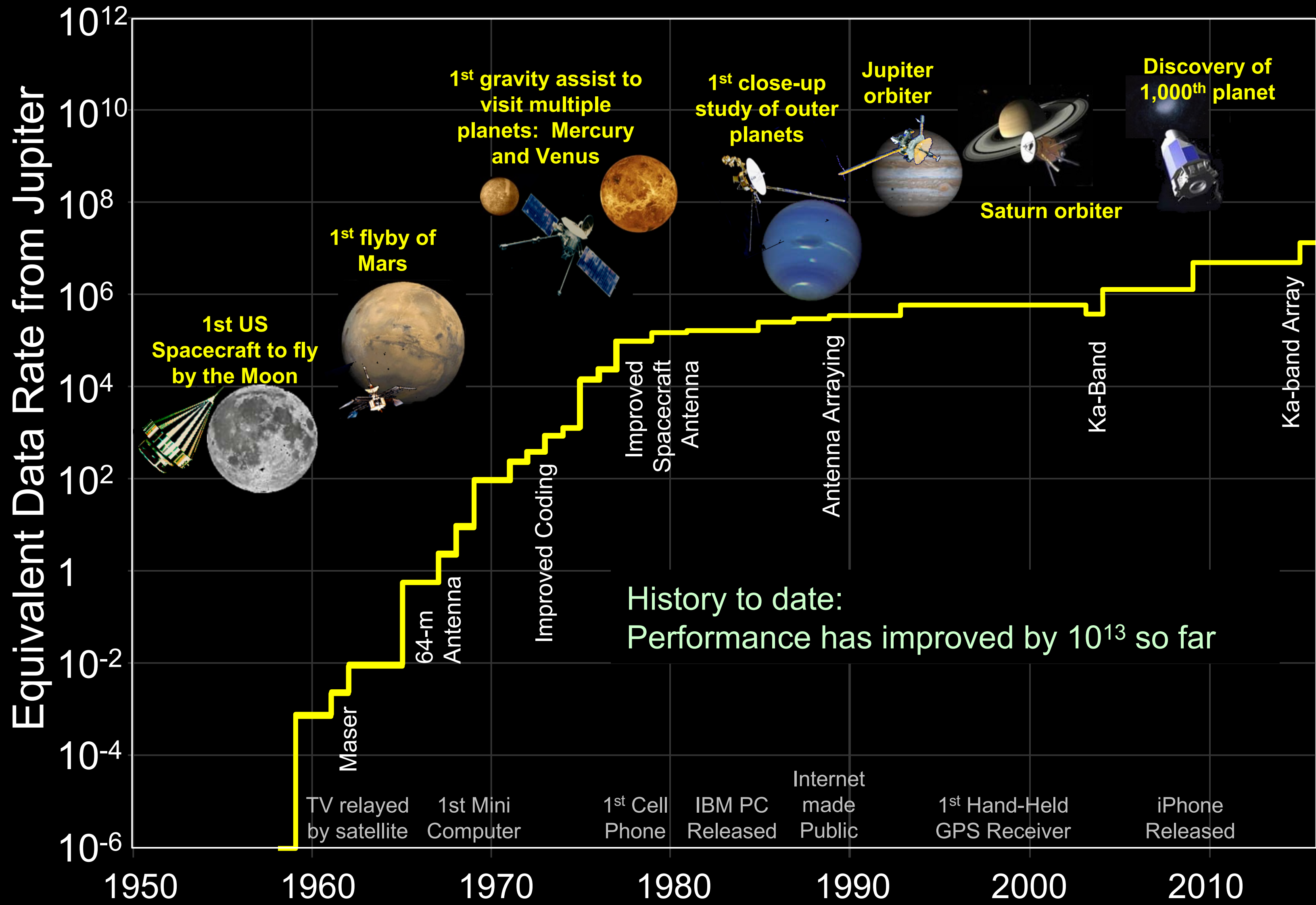


# Compression – Being stingy with bits

- Data compression is like texting
  - FYI JOE'L BRB 2 HELP L8R
  - Four your information, Joe will be right back to help later
  - Compression ratio = 39:24, or almost 2:1
- Images can be compressed 10:1
- Videos and hyperspectral images even more
- Even better: Use data onboard to answer questions and only send the answers!
  - Navigation – where am I now?
  - Locating interesting areas in a scene
  - Onboard science

# A History of Improving Communications



# Navigation using the Communications Signal

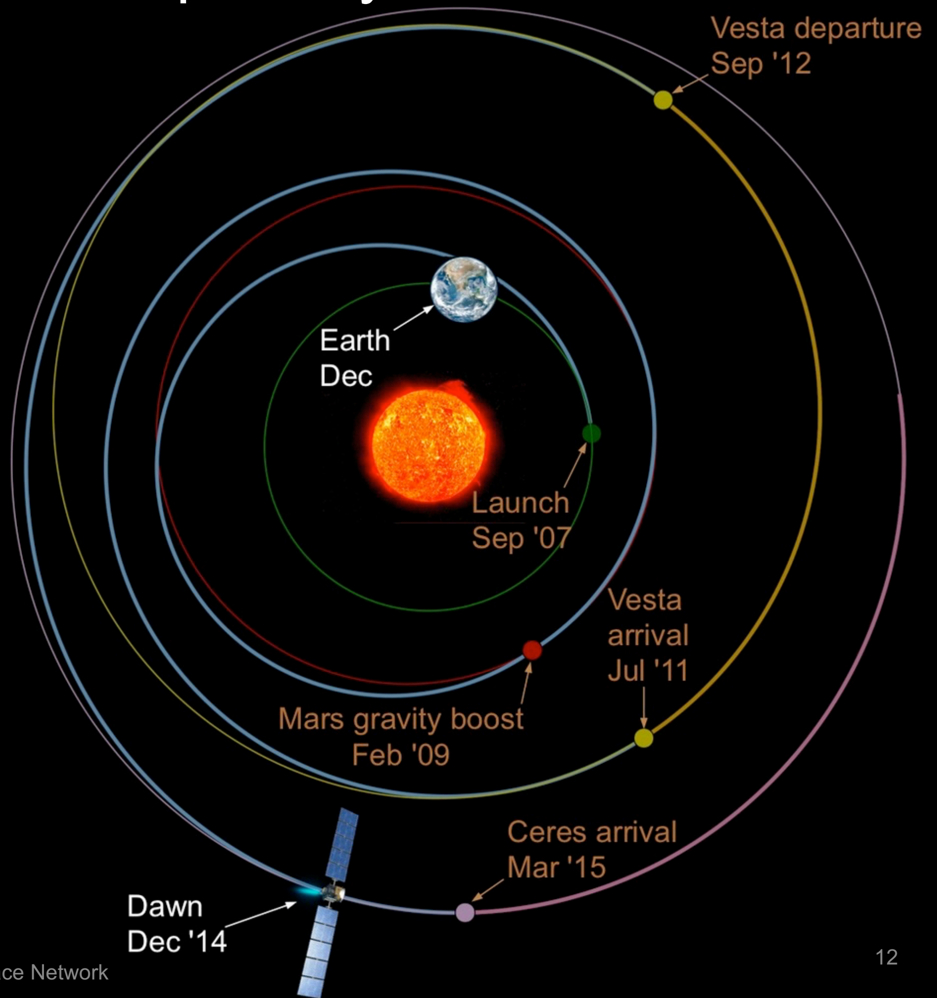
- There is no GPS in deep space
- Measurements of radio signal are the primary observables

  Ranging: measurement of the distance to the spacecraft

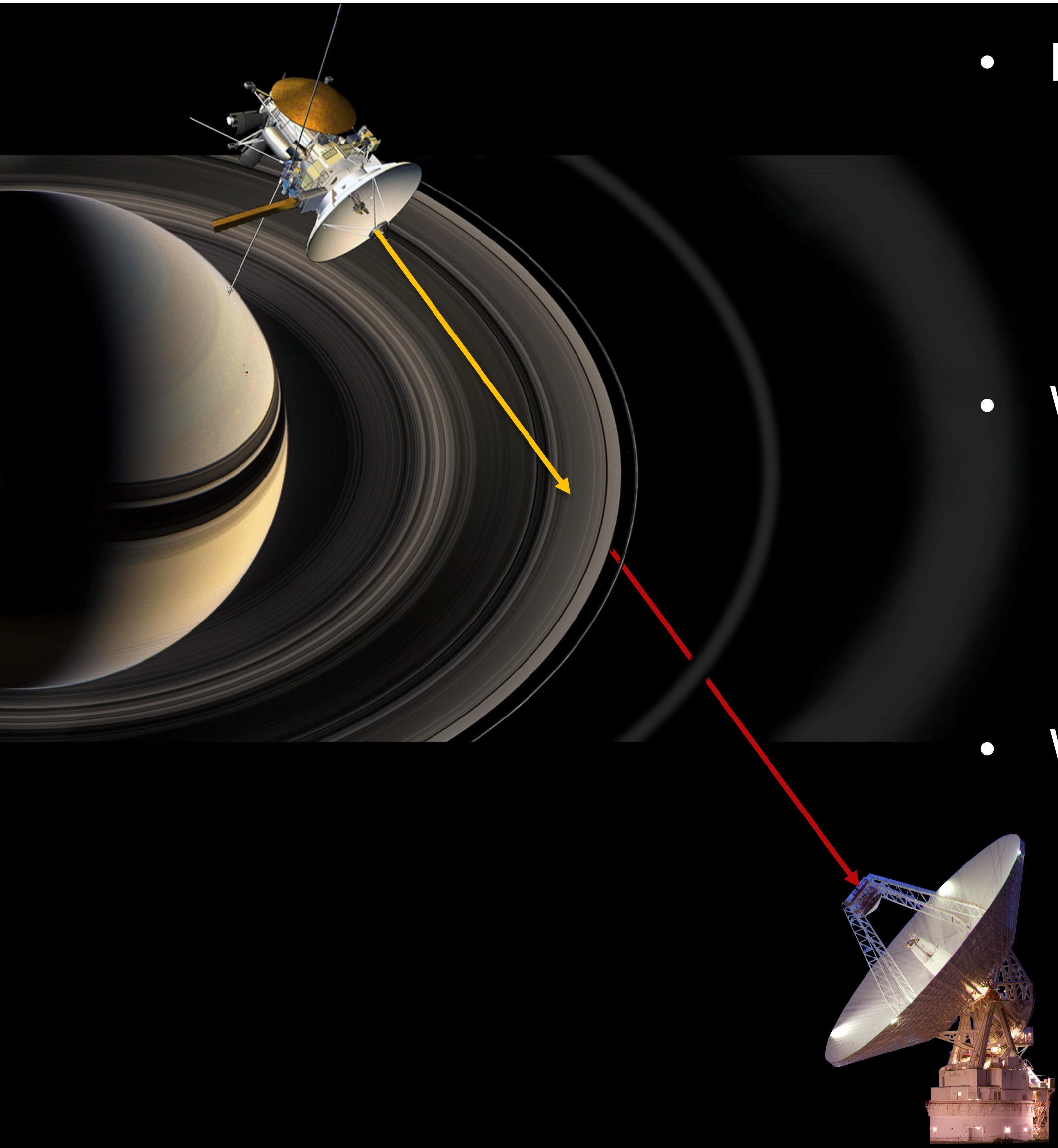
  Doppler: measurement of the relative spacecraft motion

  Delta Differenced One-Way Ranging (ΔDOR): Using multiple ground antennas to measure angle on the sky

- Supplemented with on-board sensors

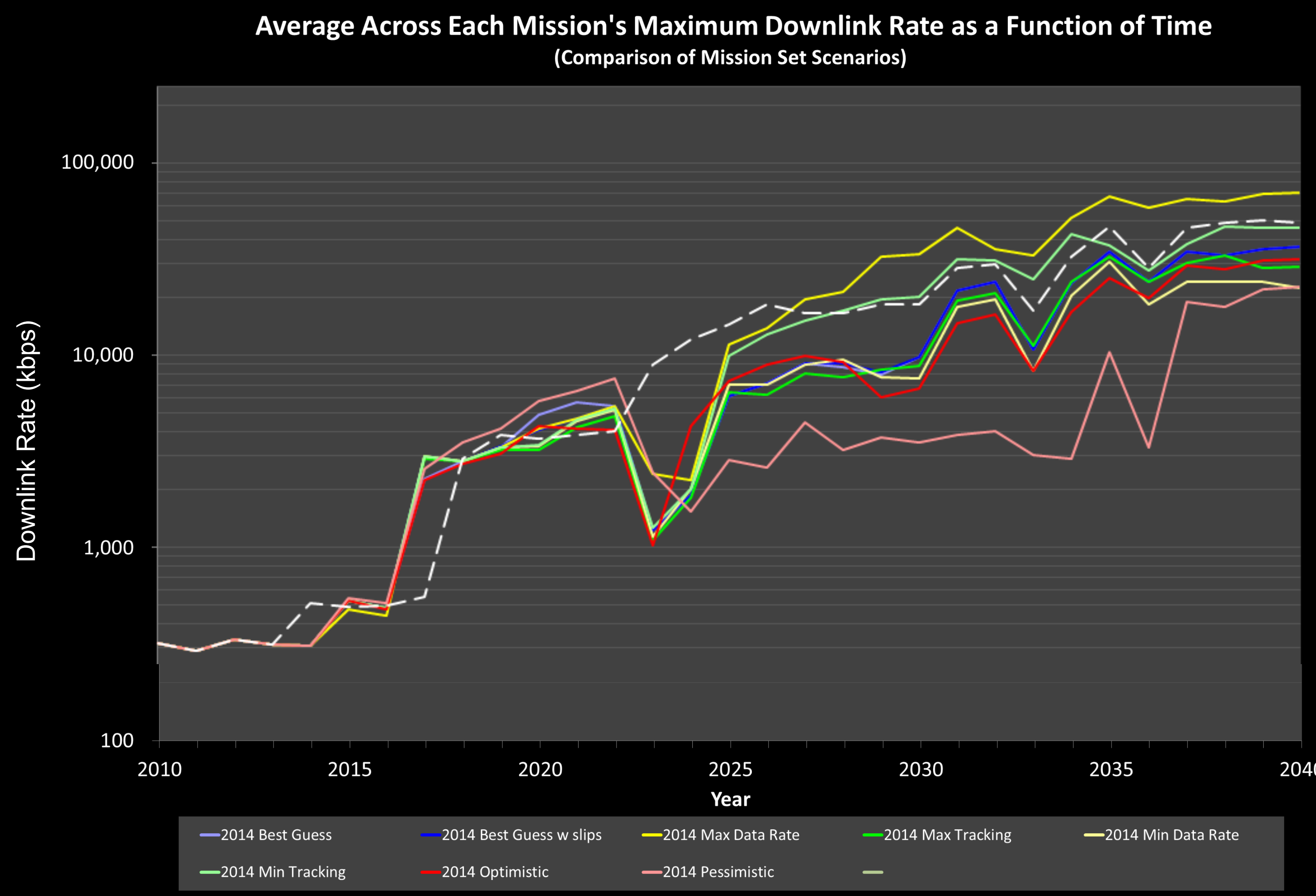


# DSN Science



- Measuring perturbations in the link
  - Attenuations
  - Spacecraft wobble
  - Frequency deviation
- We learn things about
  - Rings and particles
  - Atmospheres
  - Interiors of bodies
- We even use the DSN as a radar
  - See through atmospheres
  - Study terrain
  - Assess danger from asteroids

# Challenge: Future Missions Generate More Data



# Optical Communication in the DSN

- We will demonstrate deep space optical communications on the 2022 Psyche mission
- Uses Palomar 200” – but we need an operational capability after that
- Add mirrors to 34m DSN antennas to provide an equivalent 8m spherical aperture
- Place a photon-counting optical detector at apex
- Use separate, much smaller aperture for uplink, reducing requirements on this larger system